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Expected traffic, pavement thickness, fatigue and rutting strain relationship for low volume asphalt pavement

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ABSTRACT
The major causes of failure in asphalt pavement are fatigue cracking caused by excessive horizontal tensile strain at the bottom of asphalt layer due to repeated traffic loading and rutting deformation, caused by densification and shear deformation of subgrade. In the design of asphalt pavements, it is necessary to determine the minimum pavement thickness required to withstand the expected traffic such that fatigue and rutting strains are within the allowable minimum. This study was conducted to develop a simple relationship between expected traffic, pavement thickness, fatigue and rutting strain for cement-stabilized lateritic base, low-volume asphalt pavement. Analysis were performed for hypothetical asphalt pavement using the layered elastic analysis program EVERSTRESS. Regression equations were developed to establish a relationship between expected traffic, pavement thickness, fatigue rutting strain for cement-stabilized lateritic base, low-volume asphalt pavement. The result was validated using measured fatigue and strain data from the Kansa Accelerated Testing Laboratory (K-ATL). The calculated and measured fatigue and rutting strain were calibrated and compared using linear regression analysis. The calibration of calculated and measured fatigue and rutting strains resulted in R^2 of 0.999 and 0.994 respectively for subgrade modulus of 31MPa, 0.997 and 0.997 respectively for subgrade modulus of 41MPa, 0.996 and 0.999 respectively for subgrade modulus of 62MPa, 0.992 and 0.995 respectively for subgrade modulus of 72MPa, 0.999 and 0.998 respectively for subgrade modulus of 93MPa, and 0.999 and 0.999 respectively for subgrade modulus of 103MPa indicating that the coefficients of determination were very good.

KEYWORDS: *Expected traffic, Pavement Thickness, Fatigue and Rutting Strain, Low volume Roads.*

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I. INTRODUCTION

As a result of frequent road failure in most developing countries, the need for stronger, long-lasting and all-weather pavements has become a priority in pavement engineering as result of rapid growth in the automobile traffic and the development of modern civilization. In Pavement Engineering, it is generally known that the major causes of failure of asphalt pavement is fatigue cracking, caused by excessive horizontal tensile strain at the bottom of the asphalt layer due to repeated traffic loading and rutting deformation caused by densification and shear deformation of subgrade [1] [2] [3]. In the design of asphalt pavements, it is necessary to determine the minimum pavement thickness required to withstand the expected traffic such that fatigue and rutting strains are within the allowable minimum.

In most developing countries in Africa, the only developed design method for asphalt pavement is the California Bearing Ratio (CBR). This method uses the California Bearing Ratio and traffic volume as the sole design inputs. The method was originally developed by the U.S Corps of Engineers and modified by the British Transportation Research Laboratory [4]. Most of the roads designed using the CBR method failed soon after construction by fatigue cracking and rutting deformation. In their researches [5] [6], a comparative analysis of flexible pavements designed using three different CBR procedures were carried out, result indicated that the pavements designed by the CBR-based methods are prone to either fatigue cracking or rutting deformation or both. The CBR method was abandoned in California 50 years ago [7]. It is regrettable that this old and unreliable method is still being used by most designers in some developing countries in Africa.

In pavement engineering, structural design for low volume roads considers two types of pavements; asphalt pavement with asphalt concrete surface and base course, and jointed plain concrete pavements [8]. The

National Cooperative Highway Research Program [8] defines low volume roads as roads that can withstand up to 750,000 Equivalent Single Axle Loads (ESAL) as practical maximum within a design period of 20 years.

In most developing countries in Africa, laterite is widely used as base material for construction of cost effective low-volume asphalt roads as a result of its high abundance. However, due to lack of proper consideration of the qualities and properties of laterites for use as road base material, the roads fail soon after construction. It is therefore necessary to adequately characterize such materials and improve their quality where necessary. The major focus of the study was to develop relationship between expected traffic, pavement thickness, fatigue and rutting strain such that fatigue and rutting strains developed due to traffic loading are within the allowable limit to prevent fatigue cracking and rutting deformation.

II. METHODS

This study used the layered elastic analysis and design approach to develop relationship between expected traffic, pavement thickness, fatigue and rutting strain for cement-stabilized lateritic-base low volume asphalt Pavement. The study was carried out follows:

1) Characterize pavement materials in terms of elastic modulus, CBR, resilient modulus and poison's ratio.
2) Obtain expected traffic data in terms equivalent single axle load needed for the entire design period .
3) Determine the minimum pavement thickness required to withstand expected traffic within the low volume traffic range.
4) Compute fatigue and rutting strains using layered elastic analysis based the Asphalt Institute response models.
5) Predict and evaluate pavement responses (tensile strain, compressive strain and allowable repetitions to failure).
6) Develop simple regression design equations to define the relationship between expected traffic, pavement thickness, fatigue and rutting strain such that strains are within allowable limits.

Traffic estimation is in the form of Equivalent Single Axle Load (ESAL). The elastic properties (resilient modulus for subgrade, elastic modulus for base and Poisson's ratio) of the pavement material were used as inputs for design and analysis. The resilient modulus was obtained through correlation with CBR. The layered elastic analysis program EVERSTRESS [9] was employed in all the analysis.

Pavement Material Characterization

Material characterization involves laboratory test on surface, base and subgrade materials to determine the elastic modulus of the asphalt concrete, elastic modulus of the cement-stabilized lateritic material and resilient modulus of the natural subgrade.

Asphalt Concrete Elastic Modulus

The asphalt concrete was prepared according to the Marshall method [10]. The test specimens were compacted with 35, 50, 75, 100, 125 and 150 blows using a rammer falling freely at 450mm and having a weight of 6.5kg. The elastic modulus of the asphalt concrete was determined using the Witczak model [11] in equation 1.0 at a loading frequency of 4 Hz.

$$\log E = -1.249937 + 0.029232 P_{200} - 0.001767 (P_{200})^2 - 0.002841 P_4 - 0.058097 V_a - 0.802208 \frac{V_{beff}}{(V_{beff} + V_a)} + \frac{[3.871977 - 0.0021 P_4 + 0.003958 P_{38} - 0.000017 (P_{38})^2 + 0.00547 P_{34}]}{1 e^{(-0.7919691 - 0.393532 \log \eta)}} \quad (1.0)$$

Where
E = Elastic Modulus (Psi)
η = Bituminous viscosity, in 10^6 Poise (at any temperature, degree of aging)
V_a = Percent air voids content, by volume
V_{beff} = Percent effective bitumen content, by volume
P_{34} = Percent retained on 3/4 in. sieve, by total aggregate weight(cumulative)
P_{38} = Percent retained on 3/8 in. sieve, by total aggregate weight(cumulative)
P_4 = Percent retained on No. 4 sieve, by total aggregate weight(cumulative)
P_{200} = Percent retained on No. 200 sieve, by total aggregate weight(cumulative)

The design asphalt concrete elastic modulus of 3450MPa was determined by developing a regression equation relating the compaction levels and percents air voids on one hand and the percents air voids and elastic modulus on the other hand. From the relationship, the design elastic modulus of 3450MPa was obtained for percentage air voids of 3.04% and compaction level of 90 blows.

Base Elastic Modulus Determination

The base material used in the study was cement-treated laterite of elastic modulus of 329MPa or 79.5% CBR. The elastic modulus was determined by correlation with CBR [12] as presented in equation 2.0.

$$E(psi) = 250(CBR)^{1.2} \qquad (2.0)$$

To obtain a cement treated laterite of 79,5% CBR, trial CBR test were carried out at varying cement contents. From equation 2.0, elastic modulus of 329MPa corresponds with 79.5% CBR.

Subgrade Resilient Modulus Determination

The subgrade resilient modulus was determined in accordance the AASHTO Guide [13] in order to reflect actual field conditions using correlation with CBR as shown equation 3.0 [14].

$$M_r\,(psi) = 1500\ CBR \qquad (3.0)$$

Where,

Mr = Resilient modulus (psi)
CBR = California Bearing Ratio

The average CBR was determined as = 2.94%. The study approximates CBR of subgrade to the nearest whole number; hence the CBR of the subgrade was taken as 3%.

Poison's Ratio

In mechanistic-empirical design, the Poisson's ratios of pavement materials are in most cases assumed rather than determined [8]. In this study, the Poisson's ratios of the materials were selected from typical values used by various pavement agencies as presented in Literature [8] [15].

Pavement Material Properties

Asphalt concrete elastic modulus E = 3450MPa
Cement-stabilized base elastic modulus E = 329MPa (CBR = 79.5%)
Subgrade Resilient Modulus Mr = 10-103MPa (1 - 10% soaked CBR)
Poison's Ration: Asphalt Concrete – 0.35, Stabilized Base – 0.40, Subgrade – 0.45

Traffic and Wheel load Evaluation

The study considered maximum traffic repetition of 750,000 for low volume roads in terms of Equivalent Single Axle Load (ESAL) repetitions for a design period of 20years [8]. Traffic estimation is in accordance with the procedure contained in the Nigerian Highway Manual part 1 [16]. For the purpose of this study, three traffic categories (NCHRP, 2004) were considered for design; light, medium and heavy traffic as presented in Table 1.0.

Table 1.0: Traffic Categories [8]

Traffic Category	Expected 20 yr Design ESAL	Description of Expected Traffic	A.C. Surface Thickness (mm)	Stabilized Base Thickness (mm)
Light	$1 \times 10^4 – 5 \times 10^4$	50,000 ESAL max – typical of local streets or low volume country roads with very few trucks, approx. 4-5 per day, first year.	50	≥ 50
Medium	$5 \times 10^4 – 2.5 \times 10^5$	250,000 ESAL max– typical of collectors with fewer trucks and buses, approx. 23 per day, first year	75	≥ 75
Heavy	$2.5 \times 10^5 – 7.5 \times 10^5$	750,000 ESAL max. – typical of collectors with significant trucks and buses, approx. 70 per day first year.	100	≥ 100

III. LOADING CONDITIONS AND CONFIGURATION

The study considered a three layer pavement model. The static load (P) was applied on the pavement surface (the geometry of the load usually specified as a circle of a given radius) using the EVERSTRESS program [9]. The loading condition on pavement was obtained by determining the critical load configuration. From analysis, the critical loading configuration was determined to be the single, axle, single wheel since it recorded the highest maximum stresses, strains and deflections. The pavement analysis was carried out using EVERSTRESS program [9] developed by the Washington State Department of Transportation (WSDOT).
The pavement material parameters are as presented in Table 2.0.

Table 2.0: Pavement Load and material parameters

Wheel Load (kN)	Tire Pressure (kPa)	Pavement Layer Thickness (mm)		Pavement Material Moduli (MPa)			Poison's Ratio		
		A.C. Surface T_1	Base layer T_2	A.C Surface E_1	Base E_2	Subgrade E_3	A.C Surface	Base	Subgrade
40	690	50	≥ 50	3450	329	10-103	0.35	0.40	0.45
40	690	75	≥ 75	3450	329	10-103	0.35	0.40	0.45
40	690	100	≥100	3450	329	10-103	0.35	0.40	0.45

Layered Elastic Analysis of Pavement Section

The minimum thicknesses of cement-stabilized base layer were determined based on pavement response using the Asphalt Institute response model [17]. The required minimum base thickness was determined based on the expected traffic and base thickness that resulted in a maximum tensile strain and allowable repetitions to failure (N_r) such that the damage factor D is equal to unity. As presented in Table 3.0 for 31MPa subgrade resilient modulus and light traffic category, three (3) trial analysis were carried out on hypothetical pavement sections for each traffic repetition and base thickness to determine their various damage factors in terms of fatigue and rutting. A total of on hundred and fourty eight (148) trial analysis were carried. The EVERSTRESS [9] program was used to apply a static load on a circular plate placed on a single axle single wheel configuration. A tire load of 40kN and pressure of 690kpa [13] was adopted in the analysis. Non-linear regression equations relating the trial base thickness and damage factor were used to establish the minimum base thickness required to withstand the expected traffic repetition, this was obtained at damage factor of D = 1 with the rutting criterion being the controlling criterion. The same procedure was adopted for other subgrade moduli and traffic categories, The determined minimum pavement sections were futher analyzed to compute both fatigue and rutting strains for each subgrade moduli and traffic category using the EVERSTRESS [9] program. A total of one hundred and sixty pavement sections were analyzed; fifty pavement sections for the light traffic category, fifty for medium traffic and sixty pavement sections for heavy traffic. The result of the pavement responses are presented in Table 4.0 for 31MPa subgrade modulus and light traffic category.

Development of Design Equations

The expected traffic, pavement thickness, horizontal tensile (fatigue) and vertical compressive (rutting) strains for each subgrade modulus were used to develop simple nonlinear regression equations relating the expected traffic and pavement thickness; pavement thickness and fatigue strain, and pavement thickness and rutting strain. The regression equations were developed based on the nonlinear general equations 4.0 and 5.0 using the SPSS program [18]. The relationship between expected traffic and pavement thickness were best fitted using equation 4.0 while that of pavement thickness and horizontal tensile (fatigue) strain; pavement thickness and vertical compressive (rutting) strains were fitted using equation 5.0.

$$y_1 = ax^b \qquad (4.0)$$
$$y_2 = a\ln(x) + b \qquad (5.0)$$

Where, y_1 = expected traffic (ESAL)
y_2 = tensile or compressive strain (10^{-6})
x = pavement base thickness (mm)
a, b and c are constants

Presented in Table 5 are the developed pavement regression equations for 31MPa subgrade resilient modulus (3% CBR) for light, medium and heavy traffic categories.

Table 3.0: Layered Elastic Analysis to Determine Minimum Pavement thickness for Light traffic.

A.C Mod. E1 (MPa)	Base Mod. E2 (MPa)	Sub Mod. E3 (MPa)	Layer Thickness: A.C Surface T1 (mm)	Layer Thickness: Stabilized Base T2 (mm)	Layer Thickness: Total T (mm)	Expected Repetitions Ni	Fatigue Criterion: Horizontal Tensile Strain	Fatigue Criterion: Allowable Tensile Strain	Fatigue Criterion: No. of Repetition to Failure	Fatigue Criterion: D.F	Rutting Criterion: Vertical Compressive Strain	Rutting Criterion: Allowable Compressive Strain	Rutting Criterion: No. of Repetition to Failure	Rutting Criterion: D.F
3450	329	31	50	250	300	1.00E+04	2.90E-04	9.55E-04	4.75E+05	0.02	1.35E-03	1.35E-03	9.53E+03	1.05
3450	329	31	50	270	320	1.00E+04	2.85E-04	9.55E-04	5.01E+05	0.02	1.23E-03	1.35E-03	1.48E+04	0.67
3450	329	31	50	290	340	1.00E+04	2.82E-04	9.55E-04	5.22E+05	0.02	1.11E-03	1.35E-03	2.27E+04	0.44
3450	329	31	50	250	300	2.00E+04	2.90E-04	7.74E-04	4.75E+05	0.04	1.35E-03	1.16E-03	9.53E+03	2.09
3450	329	31	50	270	320	2.00E+04	2.85E-04	7.74E-04	5.01E+05	0.04	1.23E-03	1.16E-03	1.48E+04	1.35
3450	329	31	50	290	340	2.00E+04	2.82E-04	7.74E-04	5.22E+05	0.04	1.11E-03	1.16E-03	2.27E+04	0.88
3450	329	31	50	270	320	3.00E+04	2.85E-04	6.85E-04	5.01E+05	0.06	1.23E-03	1.06E-03	1.48E+04	2.02
3450	329	31	50	290	340	3.00E+04	2.82E-04	6.85E-04	5.22E+05	0.06	1.11E-03	1.06E-03	2.27E+04	1.32
3450	329	31	50	310	360	3.00E+04	2.79E-04	6.85E-04	5.38E+05	0.06	1.02E-03	1.06E-03	3.42E+04	0.88
3450	329	31	50	290	340	4.00E+04	2.82E-04	6.28E-04	5.22E+05	0.08	1.11E-03	9.93E-04	2.27E+04	1.76
3450	329	31	50	310	360	4.00E+04	2.79E-04	6.28E-04	5.38E+05	0.07	1.02E-03	9.93E-04	3.42E+04	1.17
3450	329	31	50	330	380	4.00E+04	2.77E-04	6.28E-04	5.50E+05	0.07	9.31E-04	9.93E-04	5.07E+04	0.79
3450	329	31	50	290	340	5.00E+04	2.82E-04	5.87E-04	5.22E+05	0.10	1.11E-03	9.45E-04	2.27E+04	2.20
3450	329	31	50	310	360	5.00E+04	2.79E-04	5.87E-04	5.38E+05	0.09	1.02E-03	9.45E-04	3.42E+04	1.46
3450	329	31	50	330	380	5.00E+04	2.77E-04	5.87E-04	5.50E+05	0.09	9.31E-04	9.45E-04	5.07E+04	0.99

Table 4.0: Layered Elastic Analysis of LEADFlex Pavement for Light Traffic Category.

A.C Mod. E1 (MPa)	Base Mod. E2 (MPa)	Sub Mod. E3 (MPa)	Layer Thickness: A.C Surface T1 (mm)	Layer Thickness: Stabilize Base T2 (mm)	Layer Thickness: Total T (mm)	Expected Repetitions N_i	Fatigue Criterion: Horizontal Tensile Strain	Fatigue Criterion: Allowable Tensile Strain	Fatigue Criterion: No. of Repetition to Failure	Fatigue Criterion: D.F	Rutting Criterion: Vertical Compressi-ve Strain	Rutting Criterion: Allowable Compressi-ve Strain	Rutting Criterion: No. of Repetition to Failure	Rutting Criterion: D.F
3450	329	31	50	252	302	1.00E+04	289.4E-6	955.5E-6	4.78E+05	0.02	1.339E-03	1.35E-03	1.00E+04	1.00
3450	329	31	50	284	334	2.00E+04	282.5E-6	774.5E-6	5.17E+05	0.04	1.148E-03	1.16E-03	200E+04	1.00
3450	329	31	50	303.6	353.6	3.00E+04	279.8E-6	684.9E-6	5.34E+05	0.06	1.047E-03	1.06E-03	3.00E+04	1.00
3450	329	31	50	318.1	368.1	4.00E+04	278.2E-6	627.8E-6	5.44E+05	0.07	9.808E-04	9.93E-04	4.00E+04	1.00
3450	329	31	50	328.1	378.1	5.00E+04	277.4E-6	586.7E-6	5.49E+05	0.09	9.387E-04	9.45E-04	5.00E+04	1.00

Table 5.0: Light Traffic – Expected Traffic, Pavement Thickness, Fatigue and Rutting Strain Relationship

A.C Modulus (MPa) E1 (MPa)	Base Modulus (MPa) E2 (MPa)	Subgrade: CBR (%)	Subgrade: Modulus (MPa) E3 (MPa)	Expected Traffic – Pavement Thickness Relationship	Fatigue Criterion: Tensile Strain - Pavement Thickness Relationship (10^{-6})	Rutting Criterion: Compressive Strain – Pavement Thickness Relationship (10^{-6})
3450	329	1	10	$T = 110.68(N_i)^{0.129}$ $R^2 = 1$	$\varepsilon_t = -26.85\ln(T) + 424.29$ $R^2 = 0.975$	$\varepsilon_c = -1930.98\ln(T) + 12715.12$ $R^2 = 0.998$
3450	329	2	21	$T = 92.91(Ni)^{0.136}$ $R^2 = 1$	$\varepsilon_t = -42.86\ln(T) + 528.09$ $R^2 = 0.974$	$\varepsilon_c = -1846.77\ln(T) + 12014.21$ $R^2 = 0.998$
3450	329	3	31	$T = 83.29(Ni)^{0.140}$ $R^2 = 0.999$	$\varepsilon_t = -53.71\ln(T) + 595.49$ $R^2 = 0.980$	$\varepsilon_c = -1786.67\ln(T) + 11536.74$ $R^2 = 0.999$
3450	329	4	41	$T = 74.342(Ni)^{0.146}$ $R^2 = 1$	$\varepsilon_t = -60.73\ln(T) + 638.39$ $R^2 = 0.982$	$\varepsilon_c = -1723.29\ln(T) + 11066.66$ $R^2 = 0.998$
3450	329	5	52	$T = 66.65(Ni)^{0.151}$ $R^2 = 1$	$\varepsilon_t = -66.50\ln(T) + 672.79$ $R^2 = 0.985$	$\varepsilon_c = -1661.24\ln(T) + 10614.46$ $R^2 = 0.999$
3450	329	6	62	$T = 60.35(Ni)^{0.156}$ $R^2 = 1$	$\varepsilon_t = -70.92\ln(T) + 698.39$ $R^2 = 0.987$	$\varepsilon_c = -1610.94\ln(T) + 10250.97$ $R^2 = 0.999$
3450	329	7	72	$T = 54.88(Ni)^{0.161}$ $R^2 = 0.999$	$\varepsilon_t = -73.73\ln(T) + 714.29$ $R^2 = 0.988$	$\varepsilon_c = -1556.52\ln(T) + 9873.81$ $R^2 = 0.999$
3450	329	8	82	$T = 50.12(Ni)^{0.166}$ $R^2 = 0.999$	$\varepsilon_t = -75.83\ln(T + 725.69$ $R^2 = 0.989$	$\varepsilon_c = -1509.57\ln(T) + 9545.52$ $R^2 = 0.999$
3450	329	9	93	$T = 44.99(Ni)^{0.172}$ $R^2 = 0.999$	$\varepsilon_t = -78.01\ln(T) + 737.09$ $R^2 = 0.989$	$\varepsilon_c = -1454.94\ln(T) + 9174.98$ $R^2 = 0.999$
3450	329	10	103	$T = 40.66(Ni)^{0.178}$ $R^2 = 0.999$	$\varepsilon_t = -79.17\ln(T) + 742.61$ $R^2 = 0.989$	$\varepsilon_c = -1406.04\ln(T) + 8848.93$ $R^2 = 1$

Table 6.0: Medium Traffic - Expected Traffic, Pavement Thickness, Fatigue and Rutting Strain Relationship

A.C Modulus (MPa) E1 (MPa)	Base Modulus (MPa) E2 (MPa)	Subgrade CBR (%)	Subgrade Modulus (MPa) E3 (MPa)	Expected Traffic – Pavement Thickness Relationship	Fatigue Criterion: Tensile Strain - Pavement Thickness Relationship (10^{-6})	Rutting Criterion: Compressive Strain – Pavement Thickness Relationship (10^{-6})
3450	329	1	10	$T = 104.62(N_i)^{0.131}$ $R^2 = 1$	$\varepsilon_t = -42.55\ln(T) + 540.39$ $R^2 = 0.983$	$\varepsilon_c = -1339.96\ln(T) + 9059.89$ $R^2 = 0.998$
3450	329	2	21	$T = 86.87(N_i)^{0.138}$ $R^2 = 1$	$\varepsilon_t = -54.22\ln(T) + 614.60$ $R^2 = 0.987$	$\varepsilon_c = -1274.29\ln(T) + 8517.94$ $R^2 = 0.998$
3450	329	3	31	$T = 76.76(N_i)^{0.142}$ $R^2 = 1$	$\varepsilon_t = -60.12\ln(T) + 650.75$ $R^2 = 0.989$	$\varepsilon_c = -1226.63\ln(T) + 8142.97$ $R^2 = 0.998$
3450	329	4	41	$T = 67.95(N_i)^{0.148}$ $R^2 = 1$	$\varepsilon_t = -63.35\ln(T) + 669.84$ $R^2 = 0.990$	$\varepsilon_c = -1186.13\ln(T) + 7830.42$ $R^2 = 0.999$
3450	329	5	52	$T = 60.32(N_i)^{0.153}$ $R^2 = 1$	$\varepsilon_t = -66.19\ln(T) + 685.88$ $R^2 = 0.989$	$\varepsilon_c = -1145.03\ln(T) + 7520.87$ $R^2 = 0.999$
3450	329	6	62	$T = 54.78(N_i)^{0.157}$ $R^2 = 1$	$\varepsilon_t = -67.70\ln(T) + 693.70$ $R^2 = 0.991$	$\varepsilon_c = -1110.62\ln(T) + 7265.71$ $R^2 = 0.999$
3450	329	7	72	$T = 49.48(N_i)^{0.162}$ $R^2 = 0.999$	$\varepsilon_t = -68.65\ln(T) + 698.09$ $R^2 = 0.992$	$\varepsilon_c = -1077.81\ln(T) + 7026.26$ $R^2 = 0.999$
3450	329	8	82	$T = 44.62(N_i)^{0.168}$ $R^2 = 0.999$	$\varepsilon_t = -69.17\ln(T) + 699.78$ $R^2 = 0.991$	$\varepsilon_c = -1045.53\ln(T) + 6795.21$ $R^2 = 0.999$
3450	329	9	93	$T = 40.22(N_i)^{0.173}$ $R^2 = 0.999$	$\varepsilon_t = -68.96\ln(T) + 696.90$ $R^2 = 0.991$	$\varepsilon_c = -1011.61\ln(T) + 6555.18$ $R^2 = 0.999$
3450	329	10	103	$T = 36.38(N_i)^{0.178}$ $R^2 = 0.999$	$\varepsilon_t = -68.79\ln(T) + 694.36$ $R^2 = 0.992$	$\varepsilon_c = -980.73\ln(T) + 6340.81$ $R^2 = 0.999$

Table 7.0: Heavy Traffic - Expected Traffic, Pavement Thickness, Fatigue and Rutting Strain Relationship

A.C Modulus (MPa) E1 (MPa)	Base Modulus (MPa) E2 (MPa)	Subgrade CBR (%)	Subgrade Modulus (MPa) E3 (MPa)	Expected Traffic – Pavement Thickness Relationship	Fatigue Criterion: Tensile Strain - Pavement Thickness Relationship (10^{-6})	Rutting Criterion: Compressive Strain – Pavement Thickness Relationship (10^{-6})
3450	329	1	10	$T = 98.72(N_i)0.133$ $R^2 = 1$	$\varepsilon_t = -42.42\ln(T) + 514.40$ $R^2 = 0.994$	$\varepsilon_c = -971.06\ln(T) + 6712.19$ $R^2 = 0.999$
3450	329	2	21	$T = 80.77(N_i)^{0.140}$ $R^2 = 1$	$\varepsilon_t = -49.90\ln(T) + 561.97$ $R^2 = 0.996$	$\varepsilon_c = -920.61\ln(T) + 6292.88$ $R^2 = 0.999$
3450	329	3	31	$T = 69.64(N_i)^{0.146}$ $R^2 = 1$	$\varepsilon_t = -53.73\ln(T) + 585.07$ $R^2 = 0.994$	$\varepsilon_c = -885.48\ln(T) + 6011.51$ $R^2 = 0.999$
3450	329	4	42	$T = 61.11(N_i)^{0.151}$ $R^2 = 1$	$\varepsilon_t = -55.69\ln(T) + 596.13$ $R^2 = 0.995$	$\varepsilon_c = -855.38\ln(T) + 5775.60$ $R^2 = 0.999$
3450	329	5	52	$T = 54.23(N_i)^{0.156}$ $R^2 = 1$	$\varepsilon_t = -56.90\ln(T) + 602.12$ $R^2 = 0.997$	$\varepsilon_c = -826.00\ln(T) + 5549.02$ $R^2 = 0.999$
3450	329	6	62	$T = 48.24(N_i)^{0.161}$ $R^2 = 0.999$	$\varepsilon_t = -57.22\ln(T) + 602.67$ $R^2 = 0.996$	$\varepsilon_c = -800.57\ln(T) + 5357.36$ $R^2 = 0.999$
3450	329	7	72	$T = 43.92(N_i)^{0.165}$ $R^2 = 1$	$\varepsilon_t = -56.96\ln(T) + 599.74$ $R^2 = 0.996$	$\varepsilon_c = -778.86\ln(T) + 5192.70$ $R^2 = 1$
3450	329	8	82	$T = 39.58(N_i)^{0.170}$ $R^2 = 1$	$\varepsilon_t = -56.79\ln(T) + 597.23$ $R^2 = 0.996$	$\varepsilon_c = -757.22\ln(T) + 5032.18$ $R^2 = 1$
3450	329	9	93	$T = 35.26(N_i)^{0.175}$ $R^2 = 1$	$\varepsilon_t = -55.96\ln(T) + 590.67$ $R^2 = 0.997$	$\varepsilon_c = -734.37\ln(T) + 4864.99$ $R^2 = 1$
3450	329	10	103	$T = 31.57(N_i)^{0.181}$ $R^2 = 1$	$\varepsilon_t = -54.68\ln(T) + 581.70$ $R^2 = 0.996$	$y = -714.77\ln(T) + 4722.76$ $R^2 = 1$

RESULTS AND DISCUSSION

The required minimum pavement thickness, the fatigue and rutting strains developed due to the expected traffic for the various subgade CBR are as presented in Tables 8.0a to 10.0c for light, medium and heavy traffic categories respectively.

Table 8.0a: Expected Traffic, Subgrade CBR and Pavement Thickness data for Light Traffic

Expected Traffic N_i (ESAL)	Subgrade CBR (%)/Pavement Thickness (mm)									
	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
1.00E+04	363.14	325.13	302.41	285.25	267.79	253.91	241.78	231.21	219.34	209.49
2.00E+04	397.10	357.27	333.22	315.63	297.34	282.90	270.32	259.41	247.11	237.00
3.00E+04	418.43	377.53	352.69	334.87	316.12	301.38	288.56	277.47	264.96	254.74
4.00E+04	434.25	392.59	367.18	349.24	330.15	315.21	302.24	291.04	278.40	268.12
5.00E+04	446.93	404.69	378.83	360.80	341.46	326.37	313.29	302.02	289.29	278.99

Table 8.0b: Expected Traffic Repetitions, Subgrade CBR and Pavement Thickness data for Medium Traffic

Expected Traffic N_i (ESAL)	Subgrade CBR (%)/ Pavement Thickness (mm)									
	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
5.00E+04	431.70	386.66	356.77	337.01	315.79	299.47	285.54	274.76	261.44	249.62
1.00E+05	472.73	425.47	393.67	373.41	351.12	333.90	319.47	308.69	294.74	282.40
1.50E+05	498.52	449.96	417.00	396.51	373.60	355.85	341.16	330.46	316.16	303.53
2.00E+05	517.67	468.18	434.39	413.75	390.41	372.29	357.43	346.82	332.29	319.48
2.50E+05	533.02	482.82	448.38	427.65	403.97	385.57	370.59	360.07	345.37	332.43

Table 8.0c: Expected Traffic Repetitions, CBR and Pavement Thickness data for Heavy Traffic

Expected Traffic N_i (ESAL)	Subgrade CBR (%)/ Pavement Thickness (mm)									
	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
2.50E+05	515.62	460.22	427.52	399.21	376.98	356.84	341.45	327.44	310.40	299.43
3.50E+05	539.22	482.41	449.05	420.02	397.30	376.71	360.94	346.71	329.23	318.24
4.50E+05	557.55	499.69	465.83	436.26	413.18	392.26	376.22	361.84	344.03	333.05
5.50E+05	572.63	513.93	479.68	449.68	426.32	405.14	388.89	374.40	356.32	345.37
6.50E+05	585.49	526.09	491.52	461.17	437.58	416.18	399.75	385.19	366.90	355.97
7.50E+05	596.74	536.73	501.90	471.24	447.45	425.88	409.31	394.67	376.20	365.31

Table 9.0a: Pavement Thickness, Subgrade CBR and Fatigue Strain data for Light Traffic

Pavement Thickness (mm)	Subgrade CBR (%)/Fatigue Strain (10^{-6})									
	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
209.49	280.79	299.02	308.43	313.81	317.37	319.35	320.23	320.40	320.15	319.48
268.85	274.09	288.32	295.03	298.66	300.78	301.65	301.83	301.49	300.69	299.73
328.21	268.73	279.77	284.31	286.54	287.51	287.50	287.12	286.36	285.13	283.94
387.57	264.27	272.65	275.38	276.45	276.46	275.71	274.87	273.75	272.16	270.77
446.93	260.44	266.54	267.73	267.79	266.98	265.61	264.36	262.94	261.04	259.49

Table 9.0b: Pavement Thickness, Subgrade CBR fatigue data for Medium Traffic

Pavement Thickness (mm)	Subgrade CBR (%)/Fatigue Strain (10^{-6})									
	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
249.62	305.52	315.31	318.89	320.15	320.52	320.00	319.15	317.97	316.24	314.64
320.47	294.89	301.76	303.87	304.32	303.98	303.09	301.99	300.68	299.02	297.46
391.32	286.39	290.93	291.86	291.67	290.76	289.56	288.28	286.87	285.24	283.72
462.17	279.31	281.91	281.86	281.13	279.74	278.30	276.86	275.36	273.77	272.27
533.02	273.24	274.18	273.28	272.09	270.30	268.64	267.07	265.49	263.93	262.46

Table 9.0c: Pavement Thickness, Subgrade CBR and Fatigue Strain data for Heavy Traffic

Pavement Thickness (mm)	Subgrade CBR (%)/Fatigue Strain (10^{-6})									
	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
299.43	272.53	277.45	278.71	278.59	277.68	276.41	274.96	273.42	271.59	269.92
358.89	264.84	268.41	268.98	268.50	267.38	266.04	264.64	263.13	261.46	260.02
418.35	258.34	260.76	260.74	259.97	258.65	257.27	255.91	254.43	252.88	251.63
477.81	252.70	254.13	253.60	252.57	251.09	249.67	248.34	246.88	245.44	244.37
537.27	247.73	248.27	247.30	246.03	244.42	242.96	241.66	240.22	238.88	237.95
596.74	243.27	243.04	241.66	240.19	238.44	236.95	235.68	234.26	233.00	232.21

Table 10.0a: Pavement Thickness, Subgrade CBR and Vertical Rutting Strain data for Light Traffic

Pavement Thickness (mm)	Subgrade CBR (%)/Rutting Strain (10^{-6})									
	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
209.49	2394.66	2143.82	1987.57	1856.23	1735.67	1641.02	1554.71	1477.36	1398.80	1334.10
268.85	1912.92	1683.09	1541.83	1426.31	1321.23	1239.12	1166.40	1100.75	1035.82	983.33
328.21	1527.69	1314.66	1185.39	1082.51	989.81	917.74	855.87	799.59	745.56	702.82
387.57	1206.68	1007.65	888.37	796.03	713.64	649.93	597.11	548.64	503.69	469.08
446.93	931.50	744.48	633.76	550.45	476.91	420.37	375.30	333.52	296.35	268.71

Table 10.0b: Pavement Thickness, Subgrade CBR and Rutting Strain data for Medium Traffic

Pavement Thickness (mm)	Subgrade CBR (%)/Rutting Strain (10^{-6})									
	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
249.62	**1663.39**	**1483.94**	**1372.05**	**1283.05**	**1200.37**	**1135.15**	**1076.81**	**1023.95**	**971.15**	**927.24**
320.47	**1328.60**	**1165.56**	**1065.57**	**986.70**	**914.29**	**857.67**	**807.52**	**762.72**	**718.40**	**682.21**
391.32	**1060.96**	**911.03**	**820.57**	**749.79**	**685.58**	**635.84**	**592.25**	**553.89**	**516.35**	**486.32**
462.17	**837.99**	**698.98**	**616.45**	**552.41**	**495.04**	**451.02**	**412.89**	**379.91**	**348.01**	**323.12**
533.02	**646.87**	**517.24**	**441.50**	**383.23**	**331.73**	**292.62**	**259.17**	**230.79**	**203.73**	**183.24**

Table 10.0c: Pavement Thickness, Subgrade CBR and Rutting Strain data for Heavy Traffic

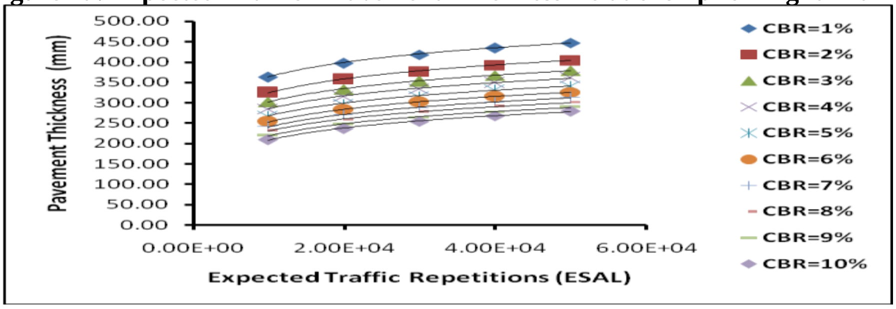
Pavement Thickness (mm)	Subgrade CBR (%)/Rutting Strain (10^{-6})									
	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
299.43	1175.32	1043.67	962.61	898.33	839.27	792.61	751.73	714.60	677.70	647.23
358.89	999.43	876.92	802.22	743.39	689.65	647.59	610.65	577.44	544.68	517.76
418.35	850.56	735.78	666.47	612.25	563.02	524.86	491.25	461.36	432.10	408.18
477.81	721.51	613.44	548.80	498.58	453.25	418.47	387.75	360.73	334.50	313.19
537.27	607.62	505.46	444.94	398.25	356.37	324.58	296.40	271.92	248.37	229.36
596.74	505.68	408.82	351.98	308.45	269.66	240.53	214.63	192.42	171.28	154.32

Expected Traffic and Pavement Thickness Relationship

The expected traffic and pavement thickness relationship are shown in Figures 1a, 1b and 1c for light medium and heavy traffic respectively. For the light traffic category, Figure 1a show that at 1% subgrade CBR, increasing the expected traffic from 1.00E+04 to 5.00E+04 ESAL resulted in an increase in pavement thickness from 363.14mm to 446.93mm while at 10% subgrade CBR, as the expected traffic increased from 1.00E+04 to 5.00E+05, the pavement thickness increased from 209.49mm to 278.99mm. The result indicates that for a subgrade CBR of 1%, a minimum pavement thickness of 446.94mm is required to with stand the maximum light traffic of 5.00E+04 ESAL while a subgrade of 10% CBR requires a minimum pavement thickness of 278.99mm to withstand the maximum light traffic for design period of 20 years. This trend was observed for all subgrade CBR.

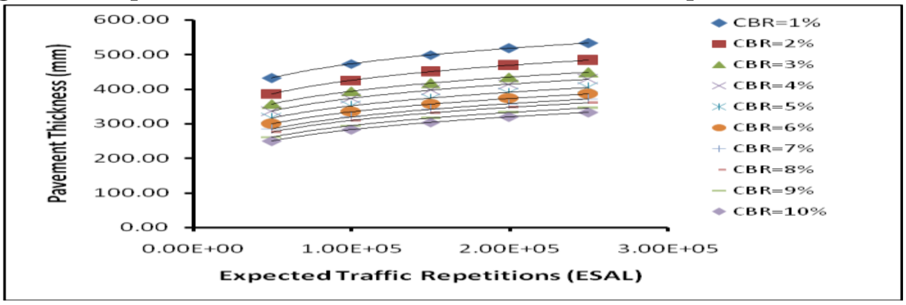
LIGHT TRAFFIC

Figure 1a: Expected Traffic – Pavement Thickness Relationship for Light Traffic



MEDIUM TRAFFIC

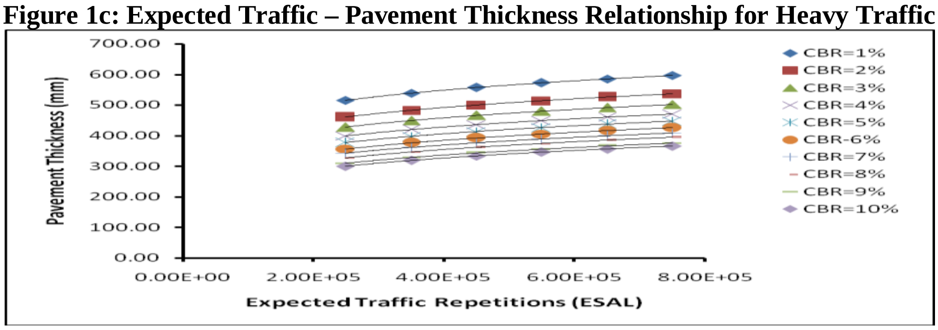
Figure 1b: Expected Traffic – Pavement Thickness Relationship for Medium Traffic



For the medium traffic category, Figure 1b shows that at subgrade 1% CBR, the pavement thickness increased from 431.70mm to 533.02mm as the expected traffic increased from 5.00E+04 to 2.50E+05, while at 10% subgrade CBR, as the expected traffic increased from 5.00E+04 to 2.50E+05, the pavement thickness increased from 249.62mm to 332.43mm. The result also indicates that for the medium traffic situation, a subgrade CBR of 1% requires a minimum pavement thickness of 533.02mm to withstand the maximum medium traffic of 2.5.0E+05 ESAL, while for a subgrade CBR of 10%, a minimum pavement thickness of 332.43mm is requires to withstand same traffic for design period of 20 years. This trend was observed for all subgrade CBR.

HEAVY TRAFFIC

Figure 1c: Expected Traffic – Pavement Thickness Relationship for Heavy Traffic



In the case of the heavy traffic category, Figure 1c shows that at 1% subgrade CBR, as the expected traffic increased from 2.50E+05 to 7.50E+05, the pavement thickness increased from 515.62mm to 596.74mm while at 10% subgrade CBR, as the expected traffic increased from 2.50E+05 to 7.50E+05 the pavement thickness increased from 299.43mm to 365.31mm. The result shows that a subgrade CBR of 1% requires a minimum pavement thickness of 596.74mm to withstand the maximum traffic of 7.5.0E+05 ESAL, while subgrade CBR of 10% requires a minimum pavement thickness of 365.31mm to withstand the maximum heavy traffic of 7.5.0E+05 ESAL for design period of 20 years. This trend was observed for all subgrade CBR. Generally, for all traffic categories, this result indicates that for each subgrade CBR, the pavement thickness increases as the expected traffic repetition increases. This trend is in accordance with previous studies [3] [16] [19].

Pavement Thickness and Fatigue Strain Relationship

The relationship between pavement thickness and rutting strain are shown in Figures 2a, 2b and 2c for light, medium and heavy traffic respectively.

LIGHT TRAFFIC

Figure 1.0a: Pavement Thickness – Horizontal Tensile Strain Relationship for light traffic

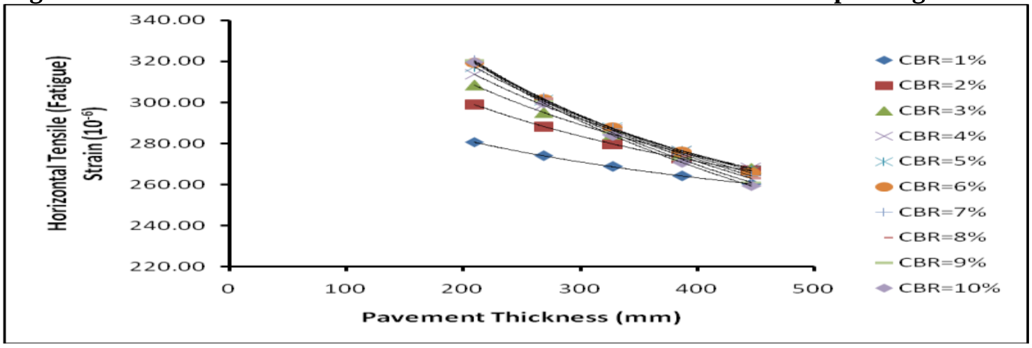
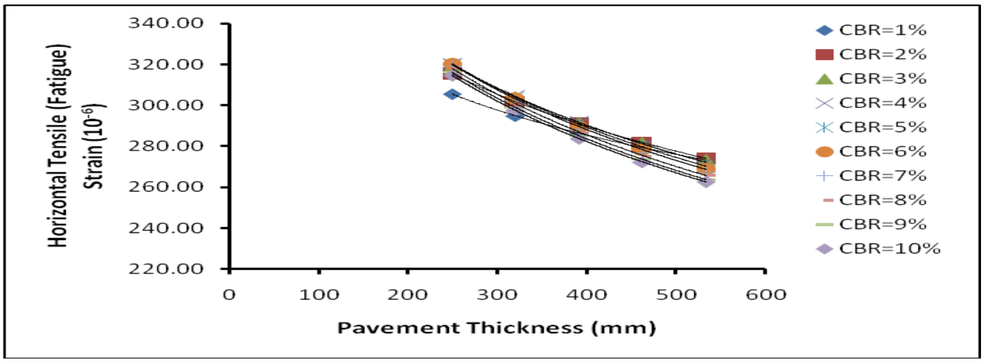


Figure 2a shows the relationship between pavement thickness and fatigue strain for light traffic category. From Figure 2a, for subgrade CBR of 1%, as the pavement thickness increased from 209.49mm to 446.93mm, the fatigue strain decreased from 280.79 x10^{-6} to 260.44 x 10^{-6} while for a subgrade CBR of 10%, as the pavement thickness increased from 209.49 to 446.93mm, the fatigue decreased from 319.48 x 10^{-6} to 259.49 x 10^{-6}. This result indicates that for the light traffic category, a subgrade CBR of 1% requires a minimum pavement thickness of 209.49mm to withstand the maximum fatigue strain of 280.79 x10^{-}6 while a subgrade CBR of 10% requires a minimum pavement thickness of 446.93mm to withstand the maximum fatigue strain of 319.48 x 10^{-6}. This result implied that for the light traffic category, about 53% increase in pavement thickness resulted in a decrease in tensile strain of about 7.8%, 12.18%, 15.21%, 17.54%, 18.87%, 20.23%, 21.13%, 21.85%, 22.64% and 23.12% for subgrade CBR of 1%, 2%, 3%, 4%, 5%. 6%, 7%, 8%, 9% and 10% respectively.

MEDIUM TRAFFIC

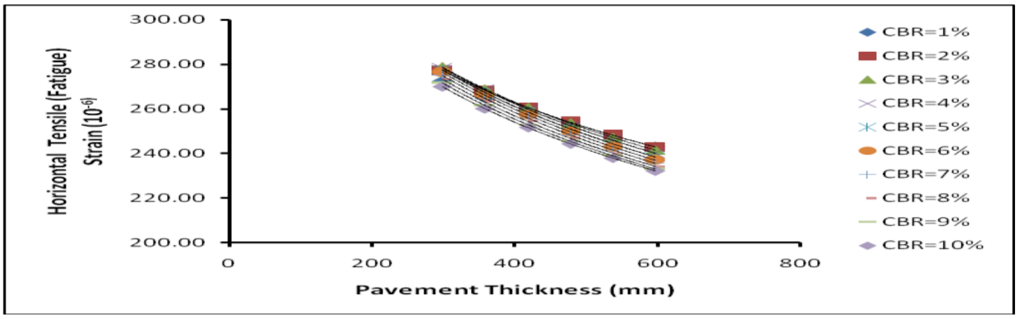
Figure 2b: Pavement Thickness – Horizontal Tensile Strain Relationship for medium traffic



The relationship between pavement thickness and fatigue strain for medium traffic category is as shown in Figure 2b. The result indicates that for a subgrade CBR of 1%, as the pavement thickness increased from 249.62mm to 533.02mm, the fatigue strain decreased from 305.52 x10^{-6} to 273.24 x 10^{-6} while for a subgrade of 10%, as the pavement thickness increased from 249.62mm to 533.02mm, the fatigue strain decreased from 314.64 x 10^{-6} to 262.46 x 10^{-6}. This result shows that for the medium traffic situation, a subgrade CBR of 1% requires a minimum pavement thickness of 249.62mm to withstand the maximum fatigue strain of 305.52 x10^{-6} while a subgrade CBR of 10% will require a minimum pavement thickness of 249.62mm to withstand a maximum fatigue strain of 314.64 x 10^{-6}. This indicates that for the medium traffic category, increasing the pavement thickness by about 53.2% reduced the tensile strain by about 11.81%, 15.00%, 16.69%, 17.66%, 18.58%, 19.11%. 19.50%, 19.77%, 19.82% and 19.88% for for subgrade CBR of 1%, 2%, 3%, 4%, 5%. 6%, 7%, 8%, 9% and 10% respectively

HEAVY TRAFFIC

Figure 2c: Pavement Thickness – Horizontal Tensile Strain Relationship for Heavy Traffic



In the case of heavy traffic category, the relationship between pavement thickness and fatigue strain is shown in Figure 2c. The result shows that for a subgrade CBR of 1%, the fatigue strain decreased from 272.53 x10^{-6} to 243.27 x 10^{-6} as the pavement thickness increased from 249.62mm to 533.02mm while for 10% subgrade CBR, the fatigue decreased from 269.92 x 10^{-6} to 232.21 x 10^{-6} as the pavement thickness increased from 249.62mm to 533.02mm. This result indicates that for the heavy traffic situation, a subgrade CBR of 1% requires a minimum pavement thickness of 249.62mm to withstand the maximum fatigue strain of 272.53 x10^{-6} while a subgrade of 10% CBR will require the minimum pavement thickness of 249.62mm to withstand the maximum fatigue strain of 269.92 x 10^{-6}. This result shows that for the heavy traffic category, increasing the pavement thickness by 49.82% caused a decrease of about 12.03%, 14.16%, 15.33%, 15.99%, 16.46%, 16.65%, 16.67%, 16.72% 16.50% and 16.23% in tensile strain for subgrade CBR of for subgrade CBR of 1%, 2%, 3%, 4%, 5%. 6%, 7%, 8%, 9% and 10% respectively.

Generally, Figures 2a, 2b and 2c shows that for particular subgrade CBR, the horizontal tensile (fatigue) strain below the asphalt layer decreases as the pavement thickness increases. This trend is in accordance with previous studies [2] [3] [16] [19] [20]

Pavement Thickness and Rutting Strain Relationship

The relationship pavement thickness and rutting strain are shown in Figures 3a, 3b and 3c for light medium and heavy traffic respectively.

LIGHT TRAFFIC

Figure 3a: Pavement Thickness – Vertical Compressive Strain Relationship for Light Traffic

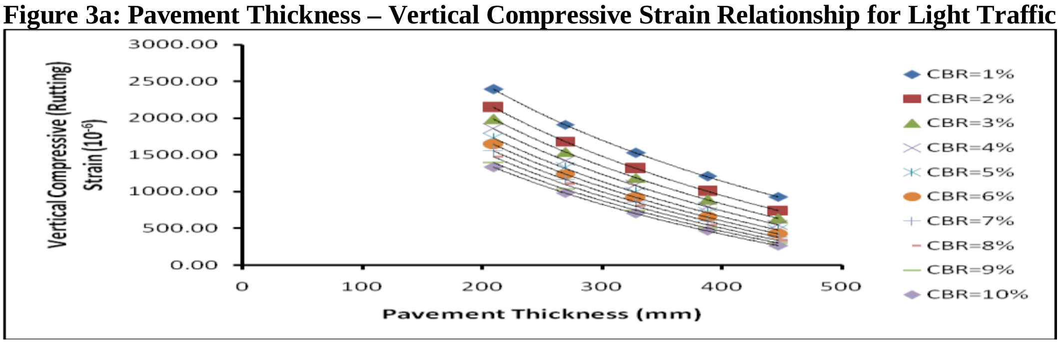
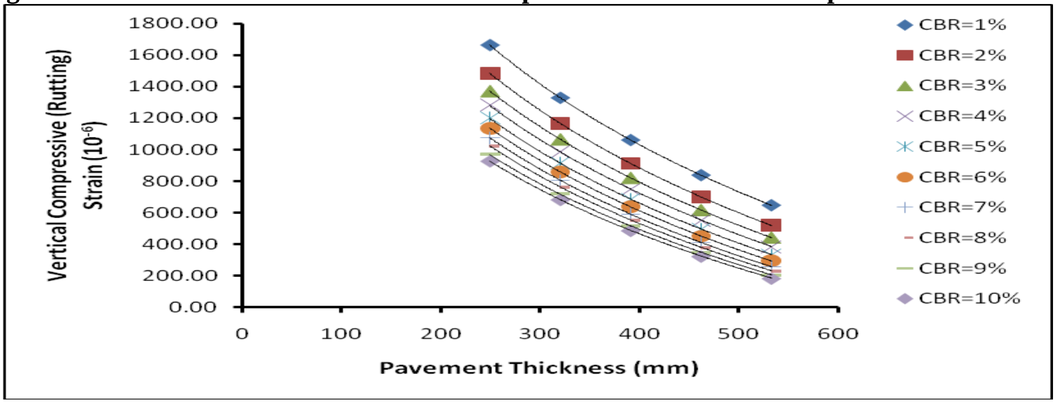


Figure 3a presents the effect of pavement thickness on rutting strain for light traffic category. Figure 3a shows that as the pavement thickness increased from 209.49mm to 446.93mm, the rutting strain decreased from 2,394.66 x10^{-6} to 931.50 x 10^{-6} and 1334.80 x 10^{-6} to 268.71 x 10^{-6} for subgrade CBR of 1% and 10% respectively. The result indicates that for subgrade CBR of 1%, a minimum pavement thickness of 209.49mm is required to withstand a maximum rutting strain of 2,394.66 x10^{-6} while a subgrade CBR of 10% requires a minimum pavement thickness of 209.49mm to withstand a maximum rutting strain of 1334.80 x 10^{-6}. The same trend was observed for other subgrade CBR. This result also shows that for the light traffic category, increasing the pavement thickness by 53.12% caused a decrease of about 157.07%, 187.96%, 213.60%, 237.22%, 263.94%, 290.38%, 314.25%, 333.96% 372.00% and 396.48% in rutting strain for subgrade CBR of for subgrade CBR of 1%, 2%, 3%, 4%, 5%. 6%, 7%, 8%, 9% and 10% respectively.

MEDIUM TRAFFIC

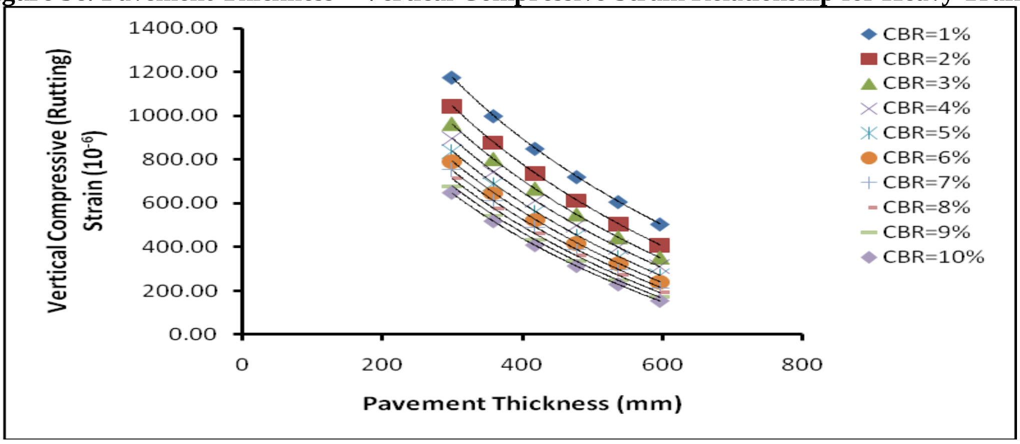
Figure 3b: Pavement Thickness – Vertical Compressive Strain Relationship for Medium Traffic



The pavement thickness and rutting strain relationship for medium traffic category is shown in Figure 3b. Result shows that for 1% subgrade CBR, the rutting strain decreased from 1663.39 x10^{-6} to 646.87 x 10^{-6} as the pavement thickness increased from 249.62mm to 533.02mm while for 10% subgrade CBR, the rutting strain decreased from 927.24 x 10^{-6} to 183.24 x 10^{-6} as the pavement thickness increased from 249.62mm to 533.02mm. The result indicates that for subgrade CBR of 1%, a minimum pavement thickness of 249.62mm is required to withstand a maximum rutting strain of 1663.39 x10^{-6} while for a subgrade CBR of 10%, a minimum pavement thickness of 249.62mm withstands a maximum rutting strain of 927.24 x 10^{-6}. The same trend was observed for other subgrade CBR. The result further indicated that for the medium traffic category, increasing the pavement thickness by 53.16% caused a decrease of about 157.14%, 186.89%, 210.77%, 234.79%, 261.85%, 287.93%, 315.48%, 343.67% 376.68% and 406.02% in rutting strain for subgrade CBR of for subgrade CBR of 1%, 2%, 3%, 4%, 5%. 6%, 7%, 8%, 9% and 10% respectively.

HEAVY TRAFFIC

Figure 3c: Pavement Thickness – Vertical Compressive Strain Relationship for Heavy Traffic



In the case of heavy traffic category, Figure 3c shows that for 1% subgrade CBR, the rutting strain decreased from 1,175.32 x10^{-6} to 505.68 x 10^{-6} as the pavement thickness increased from 299.43mm to 596.74mm while fort 10% subgrade CBR, the rutting strain decreased from 647.23 x 10^{-6} to 154.32 x 10^{-6} as the pavement thickness increased from 299.43mm to 596.74mm. The result indicates that for subgrade CBR of 1%, a minimum pavement thickness of 299.43mm is required to withstand the maximum rutting strain of 1,175.32 x10^{-6} while for 10% subgrade CBR, a minimum pavement thickness of 299.43mm is required to withstand a maximum rutting strain of 647.23 x 10^{-6}. The same trend was observed for other subgrade CBR. This result shows that for the heavy traffic category, increasing the pavement thickness by 49.82% caused a decrease of about 132.42%, 155.29%, 173.48%, 191.24%, 211.23%, 229.53%, 250.24%, 271.37%, 295.59% and 319.41% in rutting strain for subgrade CBR of for subgrade CBR of 1%, 2%, 3%, 4%, 5%. 6%, 7%, 8%, 9% and 10% respectively.

Generally, Figures 3a to 3c show that for particular subgrade CBR, the rutting strain below the asphalt layer decreases as the pavement thickness increases. This trend is in line with the result of previous researches [3] [16] [19] [21] [22]

Validation of Result

The result of the study was validated using measured tensile (fatigue) and compressive (rutting) strain data from three(3) stations at the South (SM-2A) and North (SM-2A) lanes of the K-ATL (Melhem et al, 2000). Six (6) pavement test sections were loaded using a falling weight deflectometer load of 40kN.

The average ratio of the calculated and measured fatigue and rutting strains were compared and found to be 1.04 and 1.02 respectively for subgrade modulus of 31Mpa, 1.03 and 1.03 respectively for subgrade modulus of 41MPa, 0.98 and 1.01 respectively for subgrade modulus of 62Mpa, 1.02 and 1.02 respectively for subgrade modulus of 72MPa, 1.04 and 1.00 respectively for subgrade modulus of 93MPa, and 1.03 and 1.03 respectively for subgrade modulus of 103MPa .

The calculated and measured fatigue and rutting strains were calibrated and compared using linear regression analysis for subgrade moduli of 31Mpa, 41Mpa, 62MPa, 72Mpa, 93MPa and 103MPa. The coefficients of determination R^2 were found to be very good. The calibration of calculated and measured fatigue and rutting strain resulted in R^2 of 0.999 and 0.994 respectively for subgrade modulus of 31MPa, 0.997 and 0.997 respectively for subgrade modulus of 41MPa, 0.996 and 0.999 respectively for subgrade modulus of 62MPa, 0.992 and 0.995 respectively for subgrade modulus of 72MPa, 0.999 and 0.998 respectively for subgrade modulus of 93MPa, and 0.999 and 0.999 respectively for subgrade modulus of 103MPa.

IV. CONCLUSIONS

The major findings and conclusions obtained from the study are as follows:

1) That there exist a close relationship between expected traffic and pavement thickness, pavement thickness and fatigue strain, and pavement thickness and rutting strain.
2) For particular subgrade CBR or resilient modulus, the pavement thickness increases as the expected traffic increases.
3) For particular subgrade CBR or resilient modulus, the fatigue strain decreases as pavement thickness increases.
4) That for particular subgrade CBR or resilient modulus, the rutting strain decreases as pavement thickness increases.
5) The procedure adopted and the equations developed in the study are capable of computing fatigue and rutting strain in cement-stabilized lateritic base low volume asphalt pavement.

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